



HI-CLASS on AEOS: A Large Aperture Laser Radar for Space Surveillance/Situational Awareness Investigations

**1Lt Kirstie Ayers
AFRL/DEBS**

**19th Space Control Conference
4 April 2001**

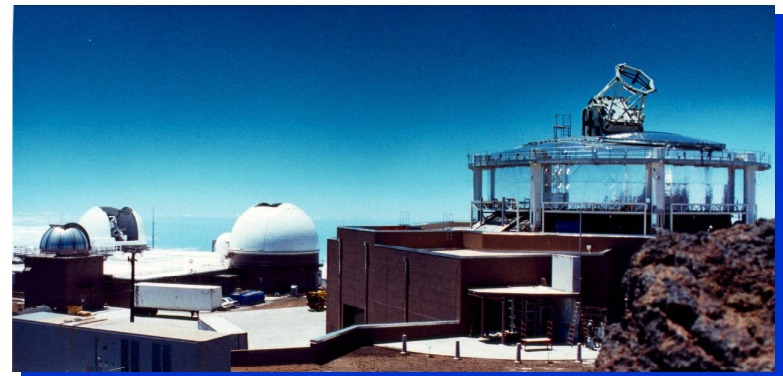
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M. Groden, D. Brown, R. Eng, M. Kovacs, P. Lewis, R. Pohle, Textron Systems
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Agenda

- **Introduction**
 - **HI-CLASS Program**
 - **Support to Mission Needs**
- **HI-CLASS System Design**
 - **0.6 m Laser Beam Director (LBD)**
 - **3.67 m Advanced Electro-Optical System (AEOS)**
- **Recent Results**
- **Current Program Activities**
- **Summary**



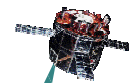
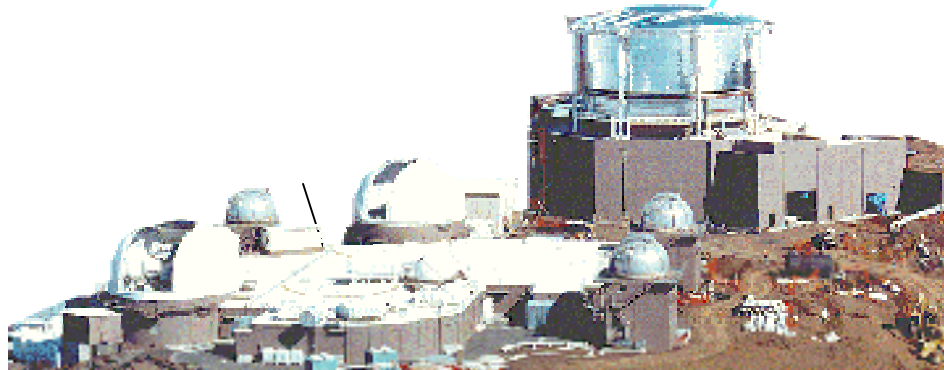
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Introduction HI-CLASS Program



High Performance CO₂ Laser
Radar Surveillance System



Two HI-CLASS Systems

at Maui Space Surveillance Complex
10,000 ft Haleakala summit, Maui, HI

- 0.6m Laser Beam Director (LBD) - 1997
- 3.67m Advanced E-O System (AEOS) - 2000

- **Active Sensing (Ladar/Lidar) Testbeds**
 - » High precision space object tracking
 - » Satellite imaging
 - » Chemical vapor detection (remote sensing)
- **Validate technologies and designs for operational systems**
- **Explore concepts and applications for surveillance platforms**
 - » Space, air, and ground



Introduction

Support to Mission Needs

- High accuracy Ladar measurements (range, range-rate, angles) for precision satellite orbit maintenance
- Sensor ranging data to calibrate operational radar/optical sensors
- Small satellites/objects (< 30 cm) tracking
- Range-cross-range data to support satellite identification, orientation, stability, structural analyses
- Field Ladar tactical demonstrations
- Theater Surveillance
- Automatic Target Recognition (ATR) technology development
- Support to compact ground, air, and space ladar applications
- Chemical-Biological Detection
 - Doppler Shift Scanning Differential Absorption Lidar (DSS DIAL)
 - Remote Sensing



HI-CLASS System Design

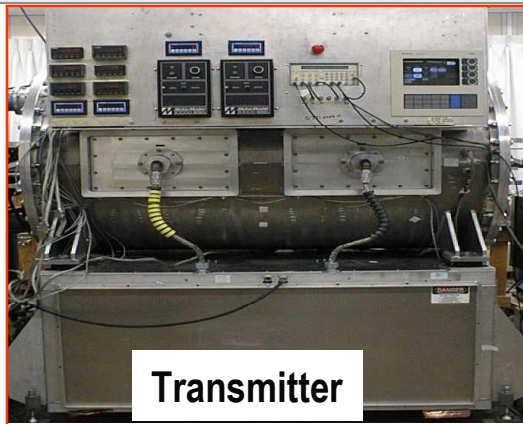
Technical Performance

LBD CO₂ Laser (for Ladar and Lidar)

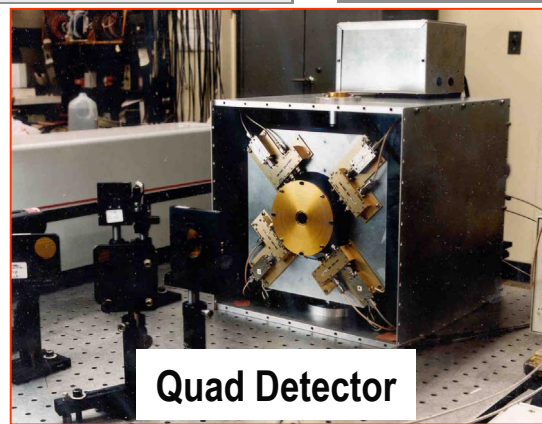
- » Power-oscillator amplifier, dual channel receiver/processor, controller
- » 30 Joule 30 Hz wideband system
- » Pulse Tone & Pulse Burst waveforms
- » 9.6-11.7 mm wavelength agile (remote sensing)
- » Dual 6 s & 15 s pulse widths
- » Dual resonators with flip mirror
- » Heterodyne receiver imaging capability (~.5 GHz bandwidth)
- » Polarization-based Transmit/Receive Switch

AEOS CO₂ Laser in Optical Room (Ladar)

- » Power-oscillator, single channel receiver/processor, controller (no amplifier)
- » 12 Joule 15 Hz wideband system
- » Pulse Tone & Pulse Burst waveforms
- » 11.13 mm wavelength
- » Single 4s pulse width
- » Single resonator
- » Heterodyne receiver imaging capability (~.5 GHz bandwidth)
- » “Holey” mirror Transmit/Receive Switch



Transmitter



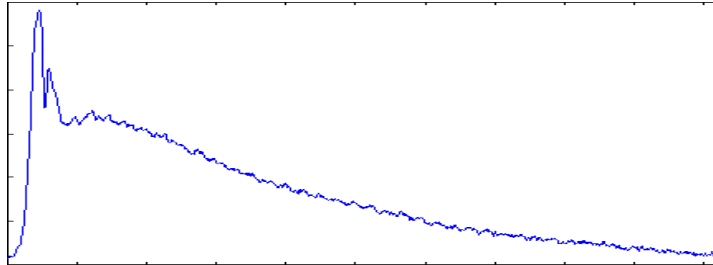
Quad Detector



Local Oscillator

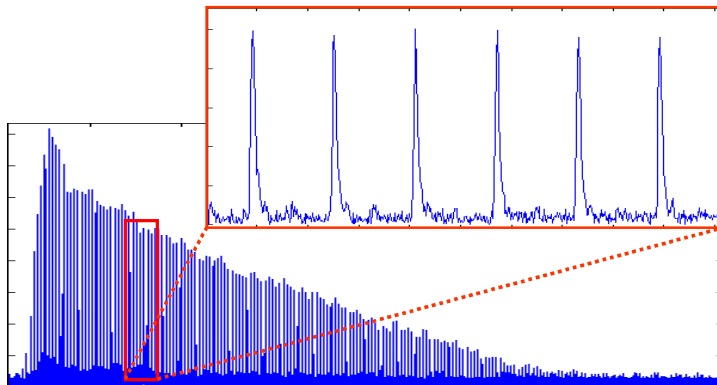


HI-CLASS System Design Waveforms



Tracking (Pulse-Tone)

Single frequency transmission
for target range and velocity
(range-rate) determination



Imaging (Pulse-Burst)

Precision imaging gives simultaneous
range and velocity
Range-Doppler (spinning targets)
Range Amplitude (non-spinning targets)

Pulsewidth: < 1.5 ns (FWHM)

Range Ambiguity: 6 m

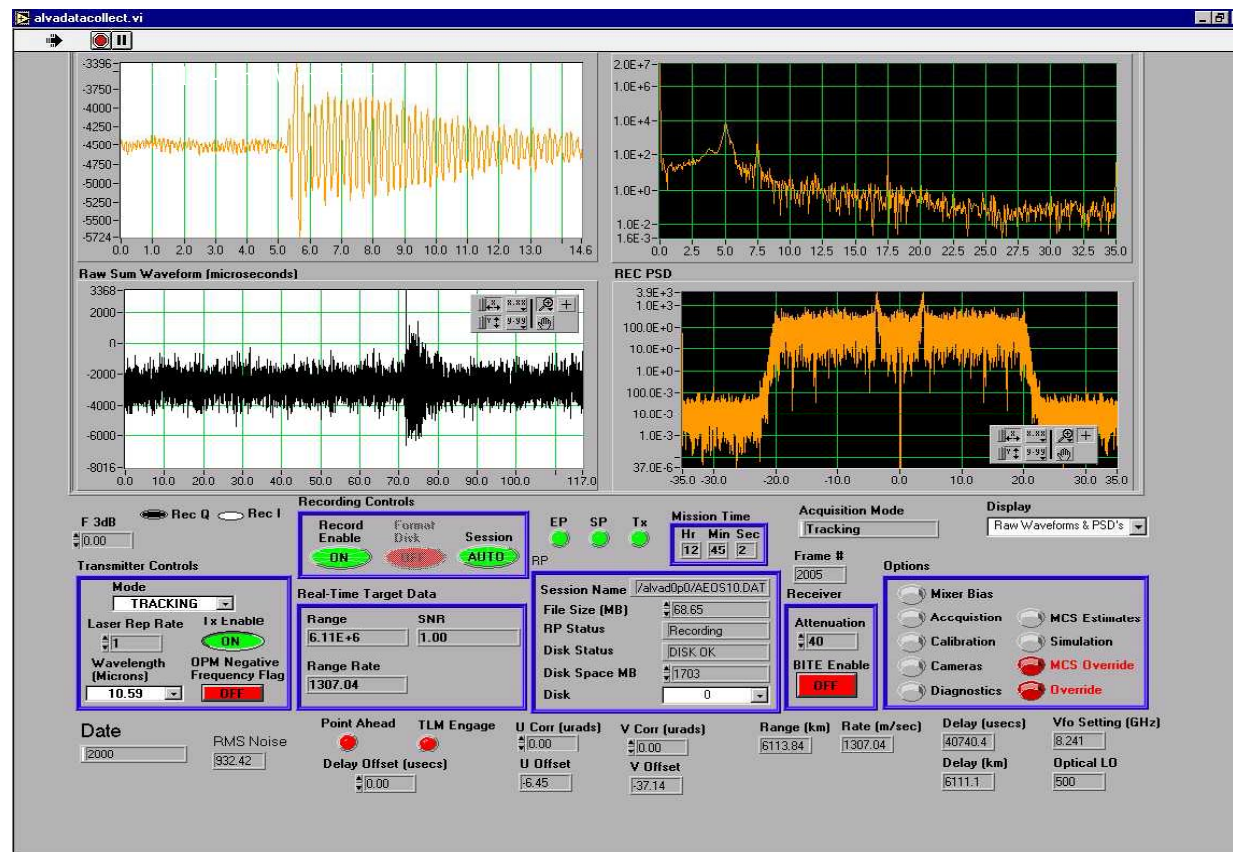
Doppler Ambiguity: 25 MHz



HI-CLASS System Design

HI-CLASS/AEOS GUI Display

User
friendly
interface



GUI showing first return from LAGEOS II satellite on 10 Nov 00



HI-CLASS System Design

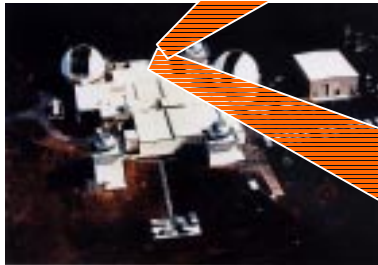
Comparison of LBD and AEOS Systems

to 2,000 km

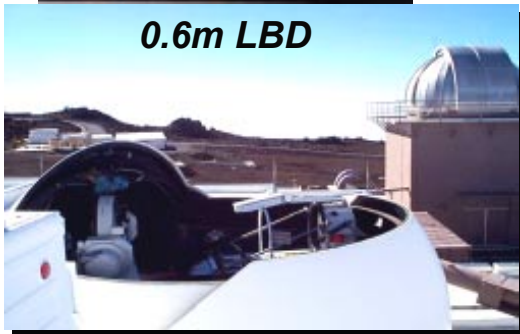
Range (m) ± 5
Rrate (m/s) ± 2

sub-meter

to 1,000 km



0.6m LBD



Precision 1m² satellite tracking

Measurement accuracy

Range-Doppler imaging spatial resolution

Range-Doppler imaging range

Small object tracking to 1,000 km

Remote Sensing

3.67m AEOS (est)

to 10,000 km

Range (m) ± 4
Rrate (m/s) ± 1

sub-meter

to 5,000 km

1 cm²

3.67m AEOS



30 dB
signal
improvement



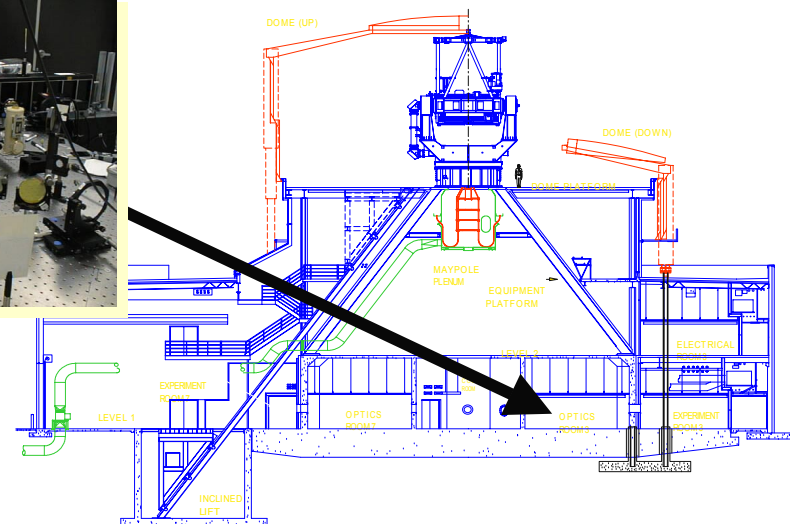
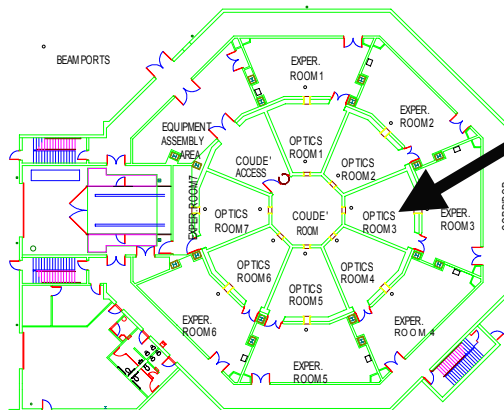
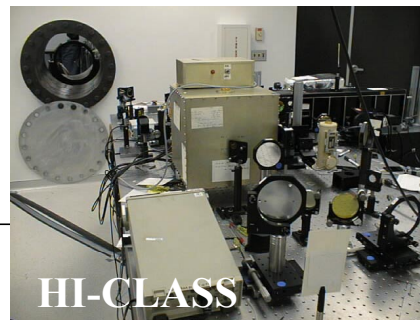
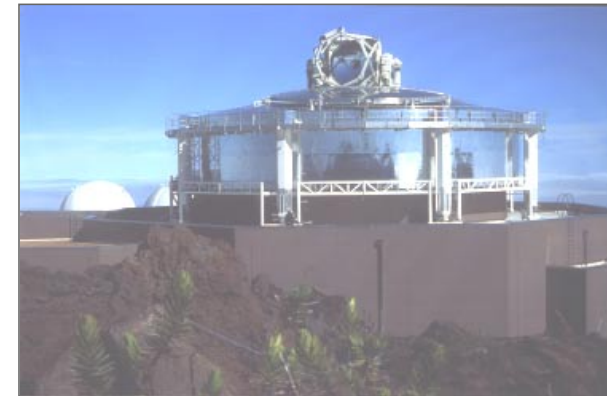
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HI-CLASS System Design Integration with AEOS

- **40,000 sq ft, 5-level facility, retractable dome**
 - Coude room with 7 optics/experiment suites
 - Both transmit and receive
- **120 ton telescope with active primary mirror cell**
- **Primary instruments**
 - Radiometer/photometer (Visible through LWIR)
 - LWIR and Visible/Near IR imaging systems
 - CO2 Ladar system
- **State-of-the-art atmospheric compensation**

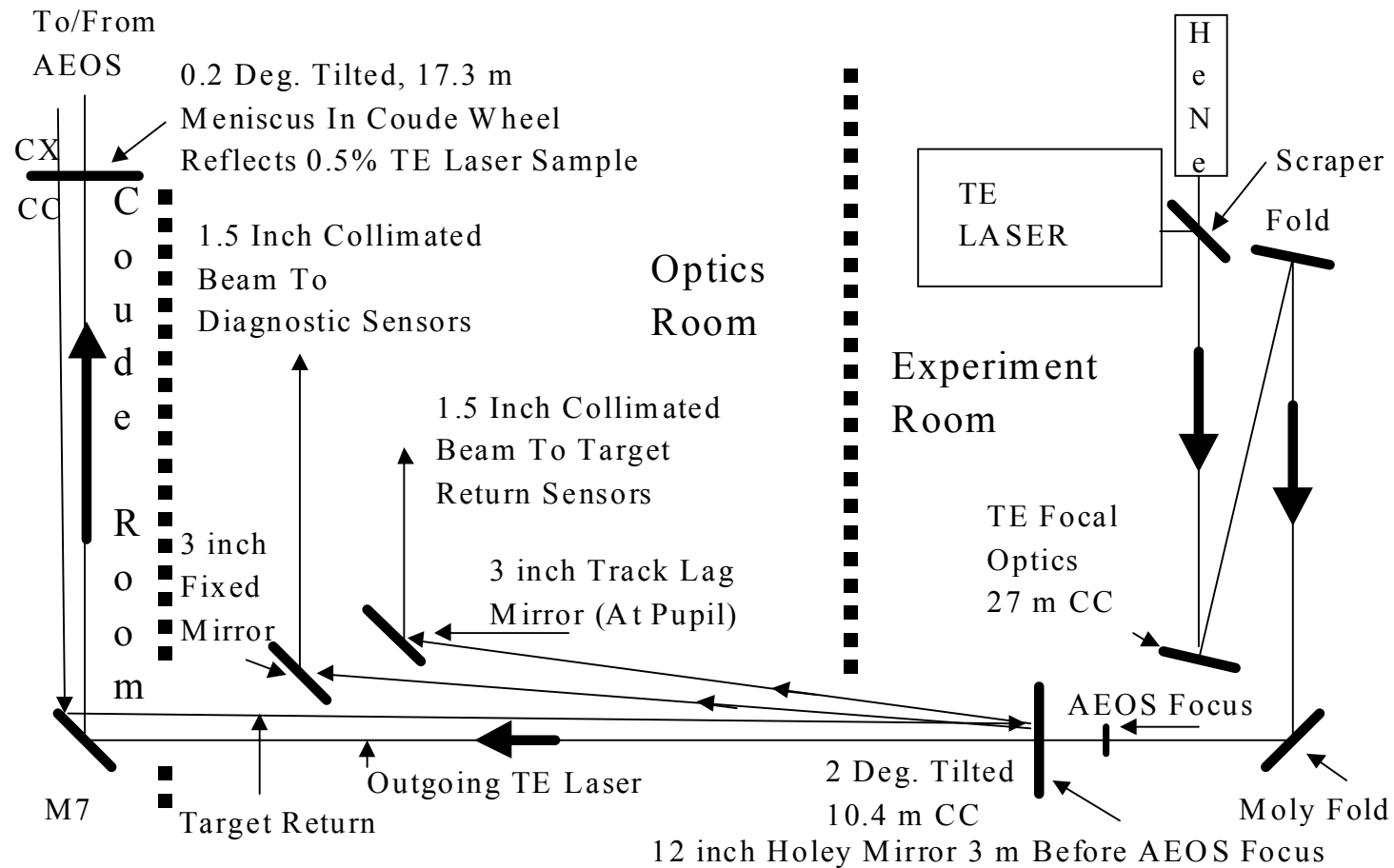


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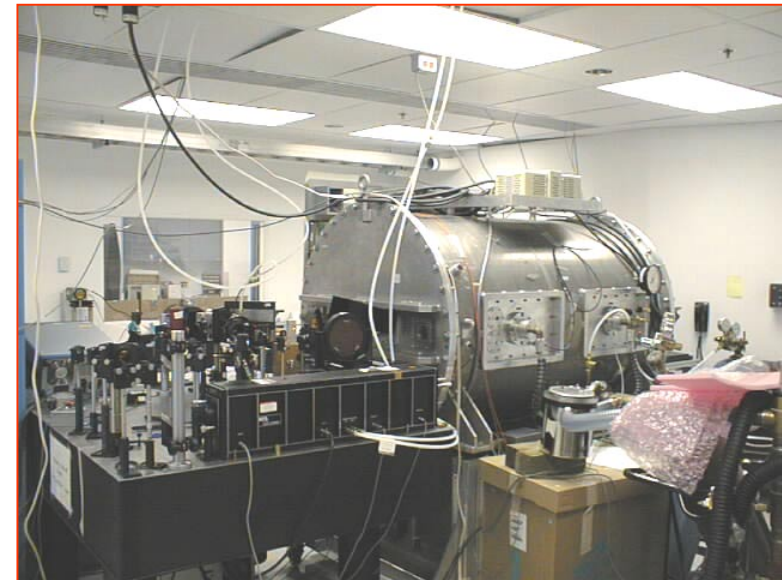
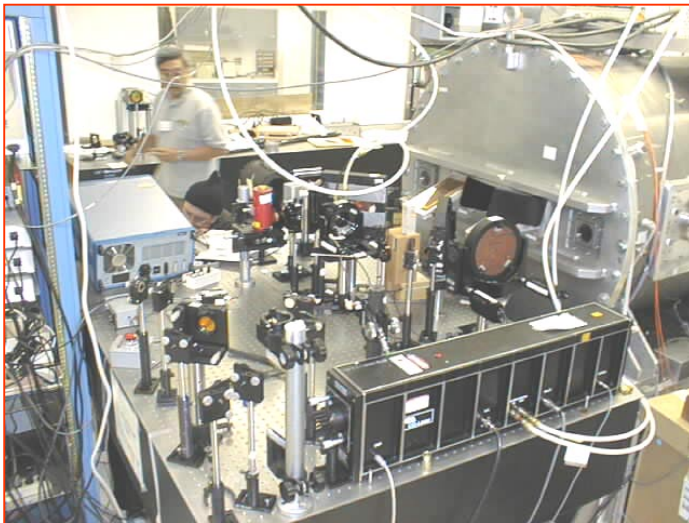
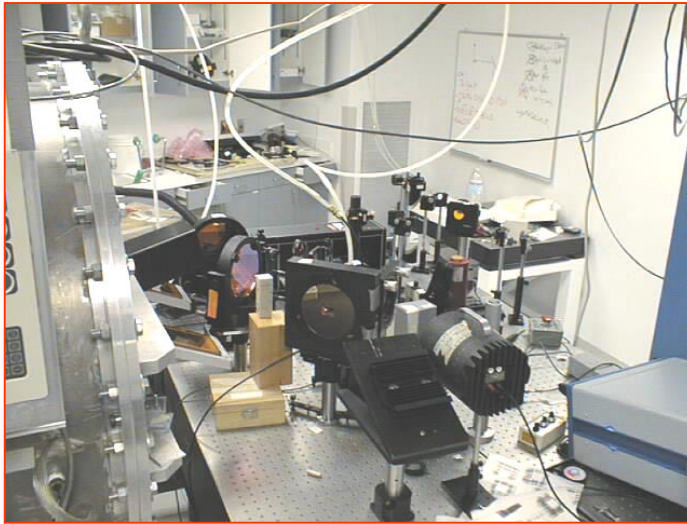
HI-CLASS System Design

AEOS Beam Train





HI-CLASS System Design Equipment

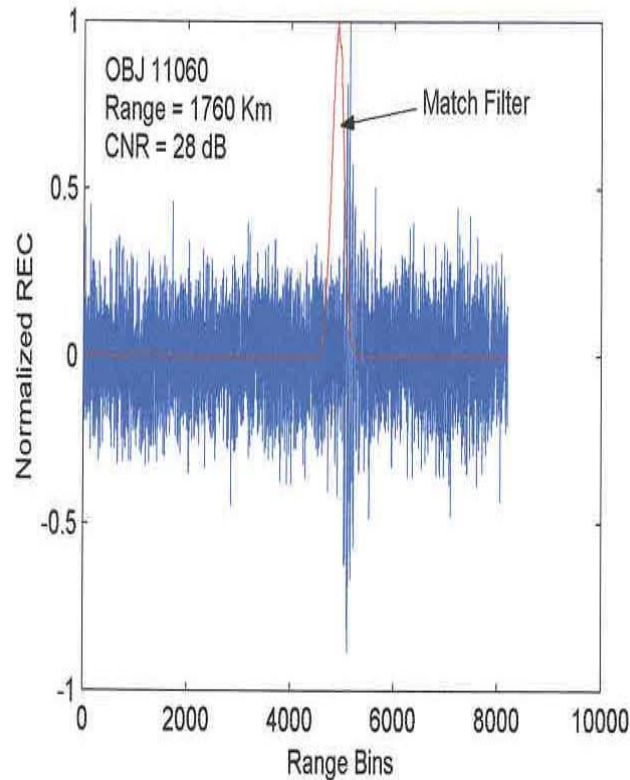


Transmitter and Optics

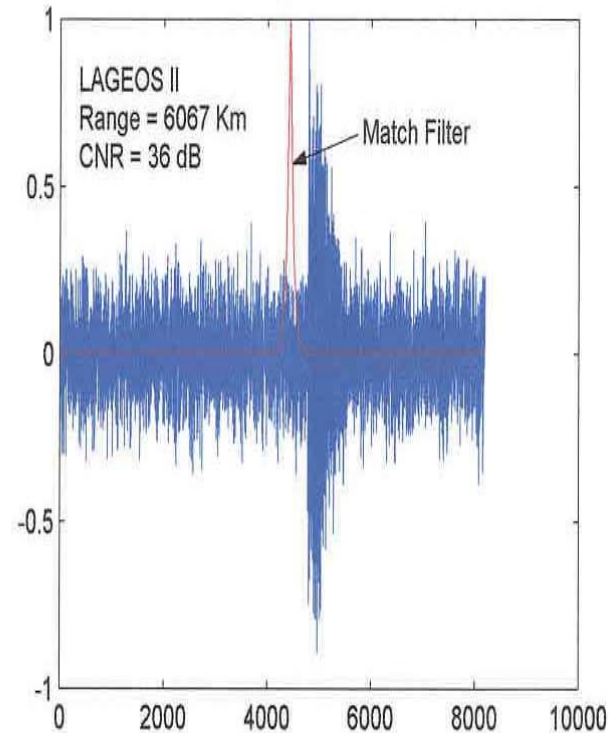
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Recent Results HI-CLASS/AEOS Returns



uncooperative



cooperative

**Unprocessed (40 MHz bandwidth) and match-filtered return signals
from uncooperative and cooperative targets**



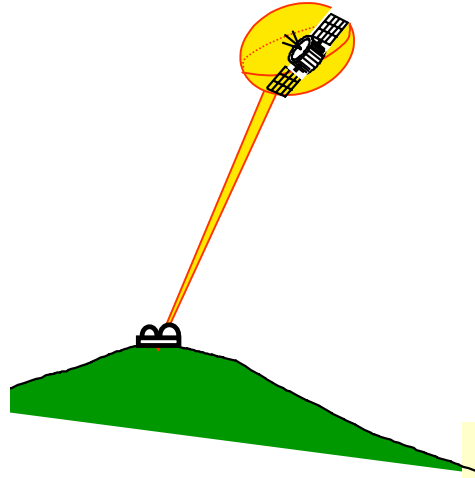
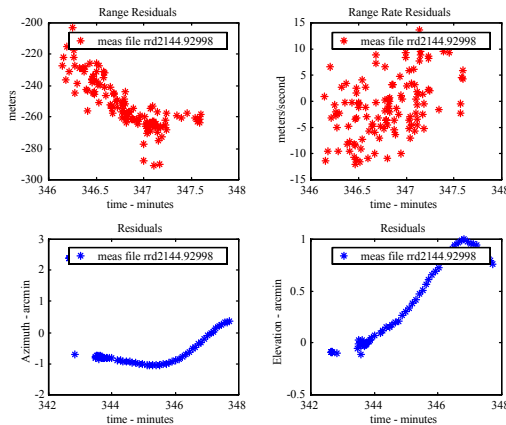
Current Program Activities

- **Complete Space Catalog Maintenance Analysis**
- **Collect Data to Support Experiments for Automatic Target Recognition (ATR) program**
- **Continue planning for AFRL-NASA Laser Space Calibration Experiment for Small Objects (FY02)**
- **Find users for Experimenter's Table in HI-CLASS suite**
- **Complete System Testing and Operational Utility Demonstrations**



Current Program Activities

Space Catalog Maintenance Analysis



Goals

- Use Ladar data (angles, range, range-rate) for Space Object Catalog Maintenance

Benefits

- More accurate ladar data can enhance orbital accuracies
 - » Reduce orbit positional/prediction errors
 - » Reduce sensor revisit times
- Combination of very accurate angles, range, and range-rate from one sensor is unique capability

LBD system compared to radar

SENSOR	Range meters	Range-rate m/sec	Angles deg
HI-CLASS	6	1	0.0006
RADAR			
Average	28	13	0.02
Best	10	1	0.01

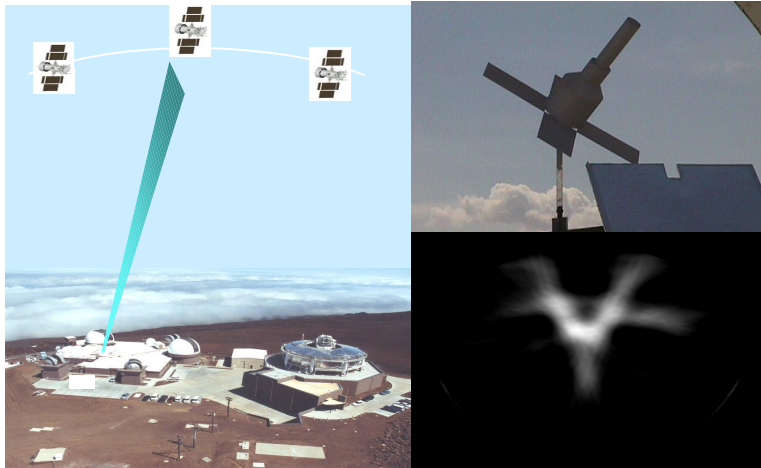
Provided by SWC/AES

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Current Program Activities

Ladar Data for Space Object Identification



Status

- Experiment to collect data in FY01
- Synergism with portable Ladar -- Laser Radar for Recognition and Assessment (LARRA)

Goals

- Use HI-CLASS ladar range-cross-range data to support Reflective Tomography imaging algorithm development
- Support data exploitation/fusion activities
- Support Space Object ID/imaging needs

Benefits

- Combination of ladar data and reflective tomography techniques can reconstruct
 - » Accurate orientation, ID, stability data
 - » Satellite image (to cm resolution)
- Provides Space Object ID/imaging data for advanced data fusion/data exploitation



Current Program Activities

AFRL-NASA Laser Space Calibration Experiment for Small Objects



Goals

- Use ladar system in joint AFRL-NASA laser space calibration experiment for small objects
- Detect/track calibration spheres (2-10 cm) released from 2002-3 Shuttle Hitchhiker experiment

Status

- Preliminary analyses
 - » Track objects > 2 cm with 10% reflectivity at 300 km range
 - » Hand-off/acquisition sensor needed
- Planning meeting held 15 Feb 01 with NASA/Marshall
- Calibration spheres design on-going
- Small object acquisition strategies under analysis

Benefits

- Provide accurate range and signature measurements of calibration spheres
 - » Calibrate optical sites (AF, NASA)
 - » Demonstrate high resolution tracking capability of small objects < 30 cm
- Support NASA small object tracking



Summary

- **Completed HI-CLASS/AEOS installation**
- **Currently performing system checkout**
- **HI-CLASS system verification will occur in the coming months**
- **Pursuing Ladar/Lidar applications that support ground, air, or space surveillance platforms**